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(54) Title: METHOD FOR PREPARING CELL CULTURES FROM BIOLOGICAL SPECIMENS FOR CHEMOTHERAPEUTIC AND OTHER ASSAYS

(57) Abstract: An improved method for preparing a cell culture is disclosed. The method includes culturing a multicellular tissue explant in the presence of growth medium that is substantially free of enzymes capable of digesting the explant and, subsequently, removing the explant at a predetermined time.

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**METHOD FOR PREPARING CELL CULTURES FROM BIOLOGICAL  
SPECIMENS FOR CHEMOTHERAPEUTIC AND OTHER ASSAYS**

**RELATED APPLICATIONS**

[0001] This application claims priority, and the benefit of U.S. Serial No. 10/208,480, filed July 30, 2002, the disclosure of which is incorporated by reference herein in its entirety.

**FIELD OF THE INVENTION**

[0002] The invention relates to methods for the preparation of a cell culture monolayer, and more particularly to methods for the preparation of a tumor cell culture monolayer that substantially comprises tumor cells.

**BACKGROUND**

[0003] Prior to approval for medical use in the United States, all pharmaceutical agents are subjected to rigorous testing for efficacy and safety. Typically, methods of assessing the efficacy of a pharmaceutical agent include complex studies of pooled patient samples or pooled data, and statistical interpretation of the results. The conclusions that follow such studies are inherently generalized or averaged over the subject patient population. With pharmaceutical agents, however, and particularly with cancer chemotherapeutic agents, the efficacy of an agent in treating an individual patient can vary greatly from the generalized data, often to the detriment of the individual patient. The need has long been recognized for a method of assessing the therapeutic potential of pharmaceutical agents, including but not limited to chemotherapeutic agents, for their specific efficacy in an individual patient.

[0004] Assays exist which expose malignant tissue of various types to pharmaceutically-active agents for the purpose of assessing the best choice for therapeutic administration. For example, in Kruczynski, A., et al., "Evidence of a direct relationship between the increase in the *in vitro* passage number of human non-small-cell lung cancer primocultures and their chemosensitivity," *Anticancer Research*, vol. 13, no. 2, pp. 507-513 (1993), chemosensitivity of non-small-cell lung cancers was investigated in *in vivo* grafts, in *in vitro* primocultures, and in commercially available cancer cell lines. The increase in chemosensitivity was documented and correlated with morphological changes in the cells in question. Often, animal model malignant cells and/or established cell cultures are tested with prospective therapy agents, see for example

Arnold, J. T., "Evaluation of chemopreventive agents in different mechanistic classes using a rat tracheal epithelial cell culture transformation assay," *Cancer Res.*, vol. 55, no. 3, pp. 537-543 (1995).

[0005] According to prior art methods of using specific patient tumor cells to form an *in vitro* assay particular to that patient, the cells are harvested (biopsied) and trypsinized (connective tissue digested with the enzyme trypsin) to yield a cell suspension suitable for conversion to the desired tissue culture form. The *in vitro* tissue culture cell preparations which result from these prior art methods typically fail to accurately replicate the chemosensitivity of the original tumor or other cell biopsy. This inability arises, in part, because the heterogeneity of cell population in the tumor tissue has been disturbed in culture, or entirely obliterated such that the cell culture preparation is essentially monoclonal. Moreover, prior art methods of culturing actual patient tissue samples inevitably result in cell cultures with a significant level of non-target cells, such as fibroblasts or other stromal cells, which have a tendency to outgrow the target tumor cells in a cell culture. Furthermore, standard cloning and tissue culture techniques are complicated and expensive for use in individualized patient testing. Thus, a need remains for improved and efficient methods of cell culture preparation that provide a heterogeneous cell population that substantially comprises target cells from a particular patient. Such a cell culture preparation is useful in drug or chemotherapeutic agent screening to provide information indicative of the *in vivo* reactivity of the cells, and thus the specific efficacy as to a particular patient.

#### SUMMARY OF THE INVENTION

[0006] The present invention provides methods for preparing a cell culture from a multicellular tissue extract. Cell cultures of the invention have the advantage of closely resembling the *in vivo* cell population from which they were obtained, thus providing an accurate and reliable proxy for the cell population *in vivo*. For example, a tumor cell culture of the invention comprises a population of cells that mimics the tumor cell population in the patient from whom a tissue explant is obtained. This allows chemosensitivity and chemoresistivity testing that is highly-reliable in predicting the effects of therapeutic agents on the tumor *in vivo*. The invention is based, in part, on the insight that timely removal of a cellular explant from culture results in a culture that is highly indicative of *in vivo* cell population. The invention provides further benefits recognized by culturing tissue explants in a growth medium that is essentially free of digestive enzymes.

[0007] Accordingly, in one aspect, the invention provides a cell culture system in which a multicellular tissue explant is placed in a growth medium and is removed from the growth medium at a predetermined time. The explant is removed prior to the emergence from the explant of a substantial number of non-target cells, resulting in a monolayer of cells that is enriched for the cell population of interest. For example, it has been discovered that cells emerge as a monolayer from a cultured tumor tissue explant in an orderly fashion, the tumor cells emerging first, followed by stromal cell populations. If the tumor cell explant remains in culture, the stromal cells have been found to dominate the tumor cells in culture. This creates a culture that is enriched from non-target stromal cells and that is not reflective of the *in vivo* cell population. Thus, in a tumor cell culture, the explant is removed from the growth medium prior to the emergence of a substantial number of stromal cells from the explant. This provides a cell culture monolayer that is predominantly composed of tumor cells. It has also been discovered that the cell cultures described above produce optimal results in cell culture medium that is essentially free of digestive enzymes.

[0008] The time at which an explant is removed from its culture medium depends upon the type of cells being cultured, the rate of emergence of various cell types, and the desired purity of the resulting cell culture monolayer. This can be determined empirically for a given cell type. In the case of tumor cells, the multicellular tissue explant is preferably removed when the cell culture monolayer is at about 10 to about 50 percent confluency. In a preferred embodiment, the multicellular tissue explant is removed at about 15 to about 25 percent confluency. In a particularly preferred embodiment, the explant is removed at about 20 percent confluency.

[0009] The invention further comprises the preparation of a cell suspension from the cell culture monolayer. A tissue explant is cultured in an appropriate medium and is removed at a predetermined time, resulting in a monolayer enriched for the cells of interest. A suspension is then made from the monolayer and cells of the suspension are inoculated into at least one segregated site. In one embodiment, a chemosensitivity assay is performed on the inoculated cell suspension by exposing the segregated site to at least one agent and assessing the chemosensitivity of the cells in the segregated site. Chemoresistivity assays are similarly performed.

[0010] In another embodiment, the invention provides methods for determining the chemosensitivity of a tissue in a patient by determining the chemosensitivity of a cell culture preparation from the patient. In yet another embodiment, the invention provides methods for identifying an agent having anti-tumorigenic effect in a patient by assessing the

chemosensitivity of segregated sites of cells from a tumor cell culture prepared according to the invention.

### DETAILED DESCRIPTION OF THE INVENTION

[0011] The present invention provides methods for preparing a cell culture monolayer by culturing a tissue sample from a patient. Ultimately, the culture may be used to screen at least one candidate therapeutic or chemotherapeutic agent for efficacy as to a specific patient, in which a tissue sample from the patient is harvested and separately exposed to a plurality of treatments and/or therapeutic agents for the purpose of objectively identifying the chemosensitivity or chemoresistivity of the tissue sample and the best treatment or agent for the patient. Tissue sample preparation techniques render this method practically as well as theoretically useful. According to the invention, the initial cohesive multicellular particulates (explants) of the tissue sample are prepared mechanically, rather than enzymatically, for initial tissue culture monolayer preparation. The multicellular tissue explant is removed from the culture growth medium at a predetermined time to both allow for the growth of target cells and prevent substantial growth of non-target cells such as fibroblasts or stromal cells.

[0012] An important application of the present invention is the screening of chemotherapeutic agents and other antineoplastic or anti-tumorigenic therapies against tissue culture preparations of tumorigenic cells from the patient from whom the sample is biopsied. Related anti-cancer therapies which can be screened using the methods of the invention are both radiation therapy and agents which enhance the cytotoxicity of radiation, as well as immunotherapeutic anti-cancer agents. Screening processes for treatment or therapeutic agents for nonmalignant syndromes are also embraced within this invention, however, and include without limitation, agents which combat hyperproliferative diseases, such as psoriasis, or wound healing agents. Nor is the present efficacy assay limited only to the screening of active agents which speed up (healing) or slow down (anti-cancer, anti-hyperproliferative) cell growth because agents intended to enhance or to subdue intracellular biochemical functions may be tested in the present tissue culture system as well. For example, the formation or blocking of enzymes, neurotransmitters and other biochemicals may be screened with the present assay methods prior to treatment of the patient.

[0013] By way of example, in one embodiment of the invention, a cell culture monolayer in accordance with the invention is prepared using the following procedure. Many aspects of the following procedure may be altered as necessary and as well known in the art. A biopsy of non-necrotic, non-contaminated tissue is harvested from the patient by any suitable biopsy or surgical



procedure known in the art. In a preferred embodiment, the tissue sample is tumor tissue. In one embodiment, the biopsy is at least about 100 mg. Biopsy sample preparation generally proceeds under sterile conditions. Cohesive multicellular particulates (explants) are prepared from the tissue sample using mechanical fragmentation. In one embodiment, this mechanical fragmentation of the explant occurs in a medium substantially free of enzymes that are capable of digesting the explant. In a preferred embodiment, the tissue sample is minced with sterile scissors to prepare the explants. In a particularly preferred embodiment, the tissue sample is systematically minced by using two sterile scalpels in a scissor-like motion, or mechanically equivalent manual or automated opposing incisor blades. This cross-cutting motion creates smooth cut edges on the resulting tissue multicellular particulates. In one embodiment, multicellular particulates measuring about  $1 \text{ mm}^3$  may be produced. After the tissue sample has been minced, the particles are plated in culture flasks (for example, 9 explants per T-25 or 20 particulates per T-75 flask). The explants may be evenly distributed across the bottom surface of the flask, followed by initial inversion for about 10-15 minutes. The flask may then be placed in a non-inverted position in a  $37^\circ \text{C}$   $\text{CO}_2$  incubator for about 5-10 minutes. In another embodiment in which the tissue sample comprises brain cells, the flasks are placed in a  $35^\circ \text{C}$ , non- $\text{CO}_2$  incubator. Flasks should be checked regularly for growth and contamination. According to a preferred embodiment of the invention, the multicellular explant is removed from the cell culture at a predetermined time, as described below. Over a period of a few weeks a monolayer will be produced. With respect to the culturing of tumor cells, it is believed (without any intention of being bound by the theory) that tumor cells grow out from the multicellular explant prior to stromal cells. Thus, by initially maintaining the tissue cells within the explant and removing the explant at a predetermined time, growth of the tumor cells (as opposed to stromal cells) into a monolayer is facilitated.

[0014] The use of the above procedure to form a cell culture monolayer culture maximizes the growth of tumor cells from the tissue sample, and thus optimizes ensuing tissue culture assay of various agents (e.g., chemotherapeutic agents) to be tested. Once a primary culture and its derived secondary monolayer tissue culture has been initiated, the growth of the cells may be monitored to oversee growth of the monolayer and ascertain the time to initiate the chemotherapy assay and to determine the growth rate of the cultured cells. Prior to the chemotherapy assay, monitoring of the growth of cells may be conducted by visual monitoring of the flasks on a periodic basis, without killing or staining the cells and without removing any cells from the culture flask. Data from periodic counting is then used to determine growth rates

which may or may not be considered parallel to growth rates of the same cells *in vivo* in the patient. If growth rate cycles can be documented, for example, then dosing of certain active agents can be customized for the patient. The same growth rate can be used to evaluate radiation treatment periodicity, as well. It should be noted that with the growth rate determinations conducted while the monolayers grow in their flasks, the present method requires no hemocytometry, flow cytometry or use of microscope slides and staining, with all their concomitant labor and cost.

[0015] Monolayer growth rate may be monitored using, for example, a phase-contrast inverted microscope. In one embodiment, culture flasks are incubated in a (5% CO<sub>2</sub>) incubator at about 37° C. The flask is placed under the phase-contrast inverted microscope, and ten fields (areas on a grid inherent to the flask) are examined using the 10X objective. In general, the ten fields should be non-contiguous, or significantly removed from one another, so that the ten fields are a representative sampling of the whole flask. Percentage cell occupancy for each field examined is noted, and averaging of these percentages then provides an estimate of overall percent confluency in the cell culture. When patient samples have been divided between two or among three or more flasks, an average cell count for the total patient sample should be calculated. The calculated average percent confluency should be entered into a process log to enable compilation of data--and plotting of growth curves--over time. Alternatively, confluency may be judged independently for each flask. Monolayer cultures may be photographed to document cell morphology and culture growth patterns. The applicable formula is:

$$\text{Percent confluency} = \frac{\text{estimate of the area occupied by cells}}{\text{total area in an observed field}}$$

As an example, therefore, if the estimate of area occupied by the cells is 30% and the total area of the field is 100%, percent confluency is 30/100, or 30%.

[0016] Following initial culturing of the multicellular tissue explant, the tissue explant is removed from the growth medium at a predetermined time. In one embodiment, the explant is removed from the growth medium prior to the emergence of a substantial number of stromal cells from the explant. Alternatively, the explant may be removed according to the percent confluency of the cell culture. In one embodiment of the invention, the explant is removed at about 10 to about 50 percent confluency. In a preferred embodiment of the invention, the explant is removed at about 15 to about 25 percent confluency. In a particularly preferred embodiment, the explant is removed at about 20 percent confluency. By removing the explant in either of the above manners, a cell culture monolayer predominantly composed of target cells

(e.g., tumor cells) is produced. In turn, a substantial number of non-target cells, such as fibroblasts or other stromal cells, fail to grow within the culture. Ultimately, this method of culturing a multicellular tissue explant and subsequently removing the explant at a predetermined time allows for increased efficiency in both the preparation of cell cultures and subsequent assays of various agents using the cultures. Adaptation of the above protocol for non-tumor cells is straightforward and generally constitutes an equivalent procedure.

[0017] The essence of the invention thus includes the important feature of the simplicity of the present system--cohesive multicellular explants of the patient tissue to be tested are used to form cell monolayers; growth of those monolayers may be monitored for accurate prediction of correlating growth of the same cells *in vivo*; explants are removed from the growth medium at a predetermined time, and differing concentrations of a number of active agents may be tested for the purpose of determining chemosensitivity of the tissue sample and the most appropriate agent and concentration of that agent for actual patient exposure (according to the calculated cell growth rates). It is also important to note, in the context of the invention, that the present system allows *in vitro* tests to be conducted in suspensions of tissue culture monolayers grown in nutrient medium under fast conditions (a matter of weeks), rather than with single cell progeny produced by dilution cloning over long periods of time. In some cases, the present invention provides a cell culture for a two stage assay for both cytotoxicity and the longer-term growth inhibitory.

#### EXAMPLE: Chemosensitivity Assay

[0018] Methods of the invention include methods for determining the efficacy of an active agent. The performance of the chemosensitivity assay used for screening purposes depends on the ability to deliver a reproducible cell number to each row in a plate and/or a series of plates, as well as the ability to achieve an even distribution of cells throughout a given well. The following exemplary procedure assures that cells are reproducibly transferred from flask to microtiter plates, and cells are evenly distributed across the surface of each well.

[0019] An initial step in preparing the microtiter plates is preparing and monitoring the monolayer as described above with the removal of the explant at 20 percent confluency. The following example shows an exemplary protocol which is susceptible of variation as will be apparent to one skilled in the art. Cells were removed from the culture flask and a cell pellet was prepared by centrifugation. The cell pellet derived from the monolayer was then suspended in 5 ml of the growth medium, mixed in a conical tube and subsequently rocked back and forth 10 times. A 30  $\mu$ l droplet from the center of the conical tube was pipetted into one well of a 96 well

plate. A fresh pipette was then used to pipette a 30  $\mu$ l aliquot of trypan blue solution, which was added to the same well, and the two droplets were mixed with repeated pipette aspiration. The resulting admixture was then applied to a hemocytometer chamber for examination using a standard light microscope. Cells were counted in all of four hemocytometer quadrants, under 10X magnification. Only those cells which had not taken up the trypan blue dye were counted. Using means known in the art, the quadrant count values were checked, logged, multiplied by  $10^4$  to give cells/ml, and the total amount of fluid (growth medium) necessary to suspend remaining cell aliquots was calculated accordingly.

[0020] After the desired concentration of cells in medium has been determined, additional cell aliquots from the monolayer were suspended in growth medium via rocking and then, loaded into a Terasaki dispenser. Aliquots of the prepared cell suspension were delivered into the microtiter plates using Terasaki dispenser techniques known in the art. Alternatively, an electronic multichannel pipettor commercially available from Matrix Technology Corp. may be used. A plurality of plates may be prepared from a single cell suspension as needed. Plates were subsequently incubated in an incubator box by means known in the art. Upon preparation of the cell suspension, cells from the suspension may be inoculated into segregated sites for subsequent assays. At least one agent may be exposed to the segregated sites to determine the chemosensitivity of the tissue samples, as well as the therapeutic or chemotherapeutic effects of the agents on the tissue sample.

[0021] The following example provides an exemplary protocol for assaying active agents in accordance with the invention. During this portion of the inventive assay, the appropriate amount of specific active agent was transferred into the microtiter plates prepared as described above. A general protocol, which may be adapted, follows. Each microtiter plate was microscopically examined for cell adhesion. Control solution was dispensed into delineated rows of wells within the grid in the microtiter plate, and appropriate aliquots of active agent to be tested were added to the remaining wells in the remaining rows. Ordinarily, sequentially increasing concentrations of the active agent being tested were administered into progressively higher numbered rows in the plate. The plates were then incubated in an incubator box at 37° C under 5% CO<sub>2</sub>. After a predefined exposure time, the plates were blotted with sterile gauze to remove the agent, washed with Hank's Balance Salt Solution, flooded with growth medium, and replaced in the incubator in an incubator box for a predefined time period, after which the plates were fixed and stained for evaluation.

## CLAIMS

What is claimed is:

1. A method for preparing a cell culture, the method comprising:  
culturing a multicellular tissue explant in the presence of growth medium that is substantially free of enzymes capable of digesting said explant; and  
removing said multicellular tissue explant from said growth medium at a predetermined time,  
thereby to produce a cell culture monolayer.
2. The method of claim 1, further comprising preparing a cell suspension from said cell culture monolayer.
3. The method of claim 1, further comprising inoculating cells from said cell culture monolayer into at least one segregated site.
4. The method of claim 1, wherein said tissue explant comprises tumor tissue.
5. The method of claim 1, further comprising the step of mechanically fragmenting the multicellular tissue explant in a medium that is free of enzymes that are capable of digesting said explant.
6. The method of claim 1, comprising the step of removing said multicellular tissue explant from said growth medium prior to an emergence of a substantial number of stromal cells from said explant, thereby to produce a cell culture monolayer that is predominantly composed of non-stromal cells.
7. The method of claim 6 wherein said non-stromal cells comprise tumor cells.
8. The method of claim 1, wherein the cell culture monolayer exhibits a percent confluency, and wherein the step of removing said multicellular tissue explant comprises removing said multicellular tissue explant at about 10 to about 50 percent confluency.
9. The method of claim 8, wherein the step of removing said multicellular tissue explant comprises removing said multicellular tissue explant at about 15 to about 25 percent confluency.
10. The method of claim 8, wherein the step of removing said multicellular tissue explant comprises removing said multicellular tissue explant at about 20 percent confluency.
11. A cell culture preparation resulting from the method of claim 1 or 10.
12. A method for determining the chemosensitivity of a tissue in a patient to an agent, the method comprising the steps of:

[0022] Fixing and staining may be conducted according to a number of suitable procedures; the following is representative. After removal of the plates from the incubator box, culture medium were poured off and the plates were flooded with Hank's Balance Salt Solution. After repeated flooding (with agitation each time) the plates were then flooded with reagent grade ethanol for 2-5 minutes. The ethanol was then poured off. Staining was accomplished using a DAPI (4', 6-diamidino-2-phenylindole, dilactate) staining method. Each plate was flooded with a DAPI/water solution, with a concentration of about 400 nM, and allowed to stand for at least 10 minutes, after which the DAPI/water was poured into a beaker. The plates were then dipped into a beaker of running water to remove the excess DAPI. Cells per well may then be counted manually or by automated and/or computerized means, to derive data regarding chemosensitivity of cells at various concentrations of exposure. One particularly useful computer operating environment for counting cells is the commercially available Zeiss Axiovert S100 Automatic Inverted Fluorescence Microscope and Computer.

[0023] The above procedures do not change appreciably when cell growth promoters are assayed rather than cell arresting agents such as chemotherapeutic agents. The present assay allows cell death or cell growth to be monitored with equal ease. In any case, optimization of use of the present system will involve the comparative testing of a variety of candidate active agents, for selection of the best candidate for patient treatment based upon the *in vitro* results. One particularly advantageous embodiment of the above-described invention comprises a two-stage assay for cytotoxicity followed by evaluation of longer-term inhibitory effect. Chemotherapeutic agents may thus be evaluated separately for both their direct chemotherapeutic effect as well as for their longer duration efficacy.

[0024] The invention is not to be limited only to the illustrative description provided herein. Variations, modifications, and other implementations of what is described herein will occur to those of ordinary skill without departing from the spirit and scope of the invention.

- (a) culturing a multicellular tissue explant from a patient in the presence of growth medium that is substantially free of enzymes capable of digesting said explant so as to produce a cell culture monolayer;
  - (b) removing said multicellular tissue explant from said growth medium at a predetermined time;
  - (d) inoculating cells from said cell culture monolayer into at least one segregated site;
  - (e) exposing said segregated site to at least one agent; and
  - (f) assessing the chemosensitivity of said cells in said segregated site, wherein said chemosensitivity of said cells is indicative of the chemosensitivity of the tissue in the patient.
13. The method of claim 12, wherein said multicellular tissue explant comprises tumor tissue.
14. The method of claim 13, wherein the cell culture monolayer exhibits a percent confluency, and wherein the step of removing said multicellular tissue explant comprises removing said multicellular tissue explant at about 10 to about 50 percent confluency.
15. The method of claim 14, wherein the step of removing said multicellular tissue explant comprises removing said multicellular tissue explant at about 15 to about 25 percent confluency.
16. The method of claim 14, wherein the step of removing said multicellular tissue explant comprises removing said multicellular tissue explant at about 20 percent confluency.
17. A method for determining the efficacy of an agent, the method comprising the steps of:
- (a) preparing a cell culture in accordance with claim 3;
  - (b) exposing said segregated site to at least one agent; and
  - (c) assessing the chemosensitivity of said cells in said segregated site, thereby to determine the efficacy of said agent.
18. The method of claim 17, wherein the cell culture monolayer exhibits a percent confluency, and wherein the step of removing said multicellular tissue explant comprises removing said multicellular tissue explant at about 15 to about 25 percent confluency.
19. The method of claim 18, wherein the step of removing said multicellular tissue explant comprises removing said multicellular tissue explant at about 20 percent confluency.
20. A method for identifying an agent having anti-tumorigenic effect, the method comprising the steps of:
- (a) preparing a cell culture in accordance with claim 4;

- (b) inoculating cells from said cell culture monolayer into a plurality of segregated sites
- (c) exposing each of said segregated sites to an agent; and
- (d) assessing the chemosensitivity of said cells in each of said segregated sites, thereby to identify an agent having an anti-tumorigenic effect.